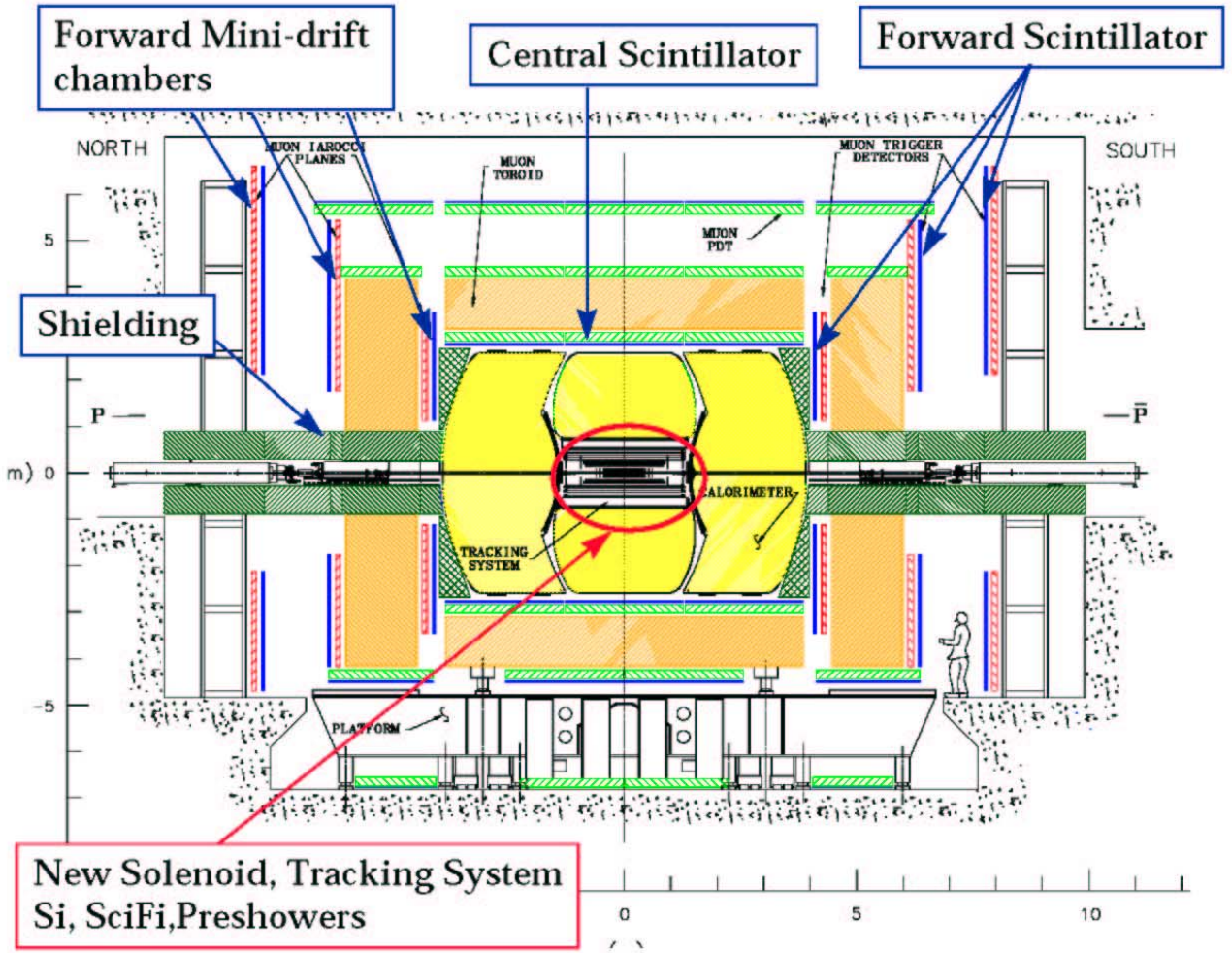
DZero Status 2003: Detector, Operations, and Physics

Jerry Blazey

On behalf of the DØ Collaboration
for the
International Finance Committee

September 19, 2003


Forward Mini-drift chambers
Central Scintillator
Forward Scintillator
Shielding
NORTH
SOUTH
MUON IAROCCI PLANES
MUON TOROID
MUON TRIGGER DETECTORS
MUON PDT
P
$\bar{P}$
m) 0
5
-5
CALORIMETER
TRACKING SYSTEM
PLATFORM
0
5
10
New Solenoid, Tracking System
Si, SciFi,Preshowers
+ New Electronics, Trig, DAQ

Detector Statistics

- **Silicon Tracker**
  - Active Channels:
    - Ladders 86%
    - F Wedges 88%
    - H Wedges 80%
  - Cluster Efficiency > 97%
- **Central Fiber Tracker**
  - Active Channels: 99% of 80k
  - Hit efficiency > 98%

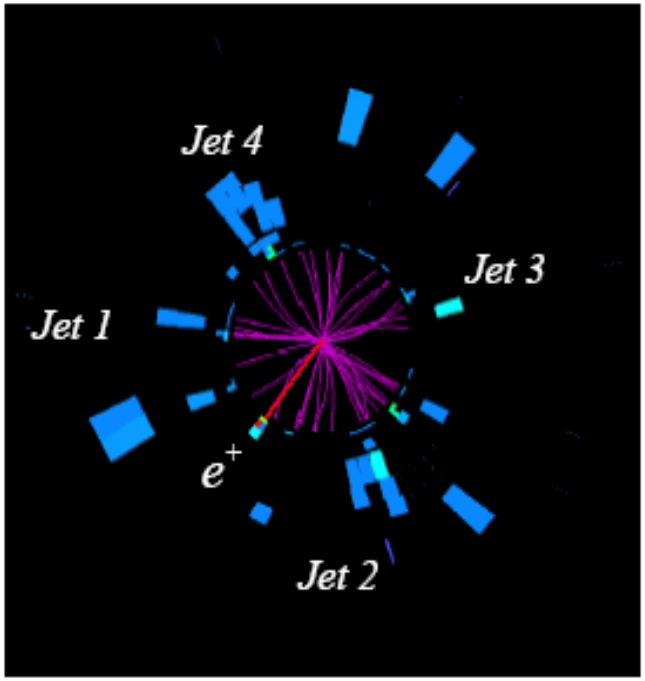
Efficiently tracking

- **Preshower**
  - Active Central Channels: 99% of 8k
  - Active Forward Channels 99% of 15k
  - First calibrations complete
- **Calorimeter**
  - Active Channels: 99.9% of 50K
  - Linear/Stable
  - Addressing Noise Issues
- **Muon**
  - Active Scintillator Channels: 99.9%
  - Active Tracking Channels 99.5%
- **FPD**
  - Installing final electronics and PMT
  - Data w/ Standalone DAQ

The detector is fully instrumented and efficient

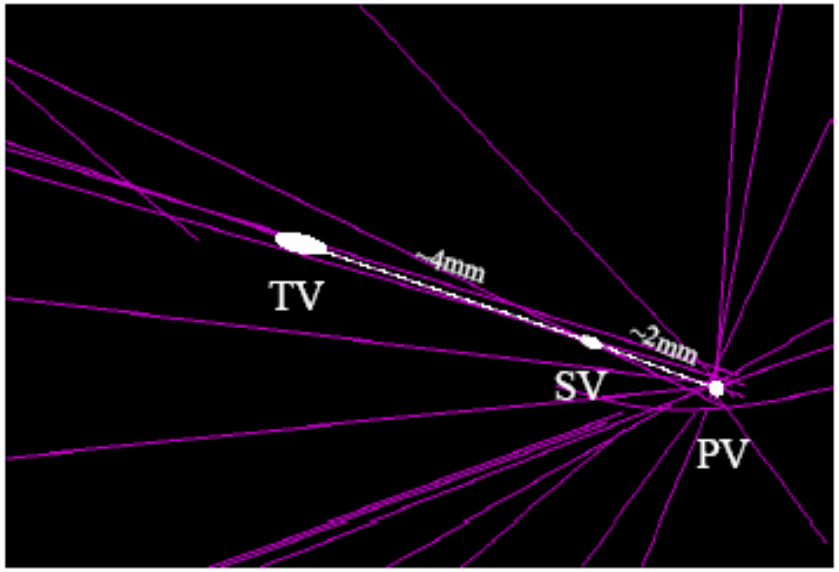
SMT Performance

Tagged event: e+jets channel



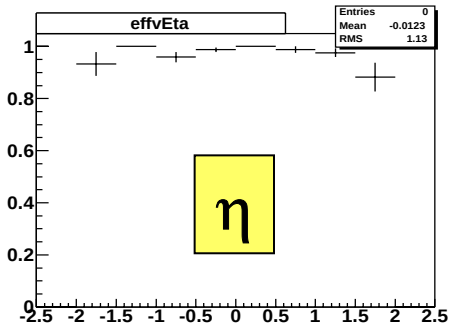
Event is tagged by both algorithms
(run 169923 event 16396718

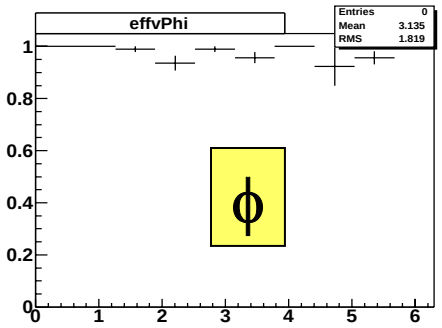
N_{jets} = 4
p_T(e) = 27 GeV
p_T(jet) = 51, 36, 30, 53 GeV
Missing E_T = 58 GeV
H_T = 207 GeV
Aplanarity = 0.11



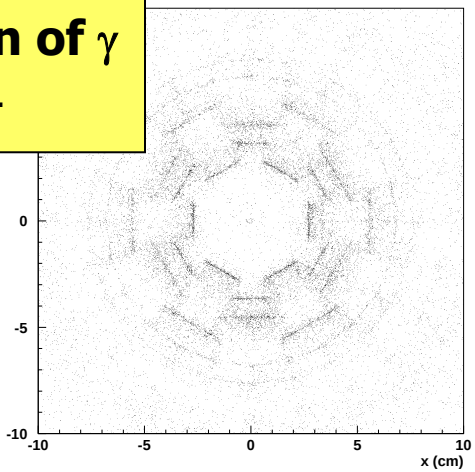
Primary vertex:
N_{track} = 17
z = –4.6 cm

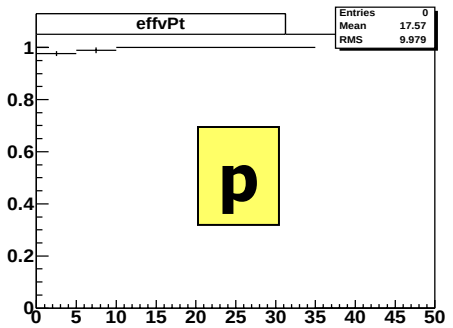
Tracking Performance

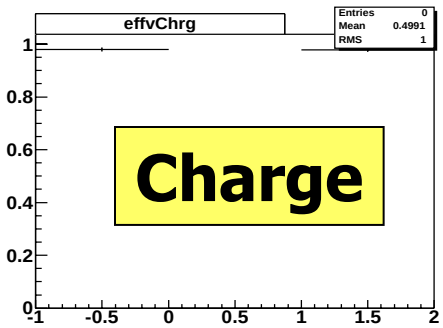




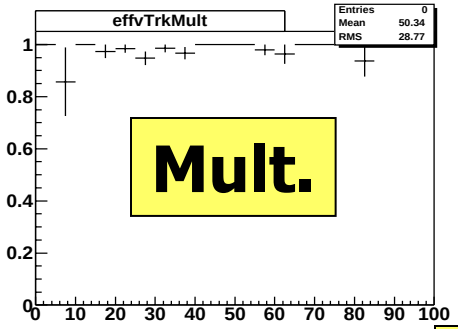
X-Y vertex location of γ to $e^+ e^-$

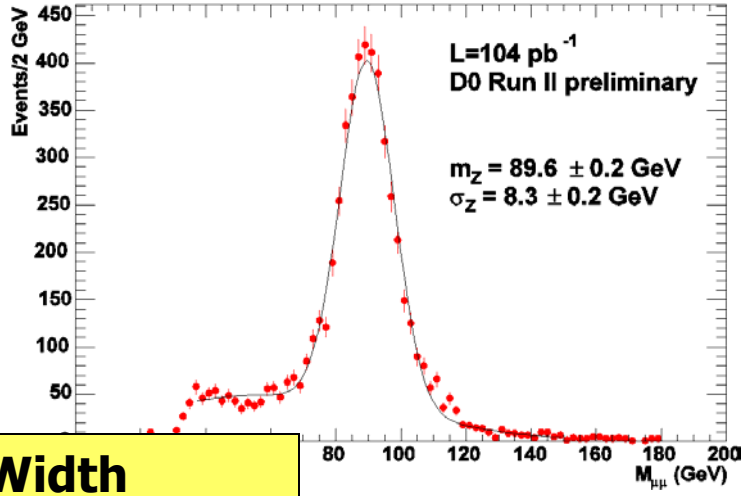






- **Tight Muons**
- **Confirmed with calorimeter confirmation**

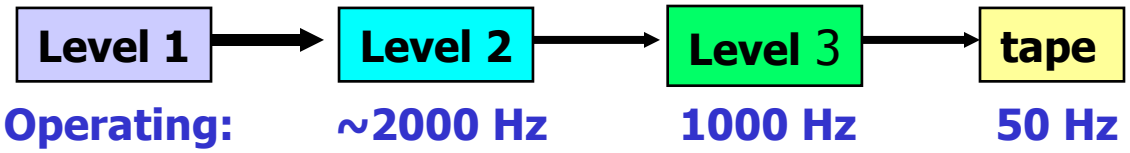




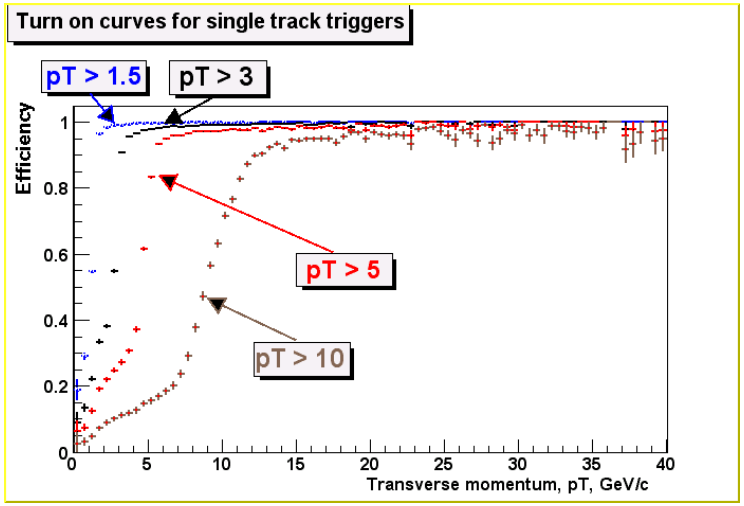
Width consistent with MC

Tracking (Efficiency)

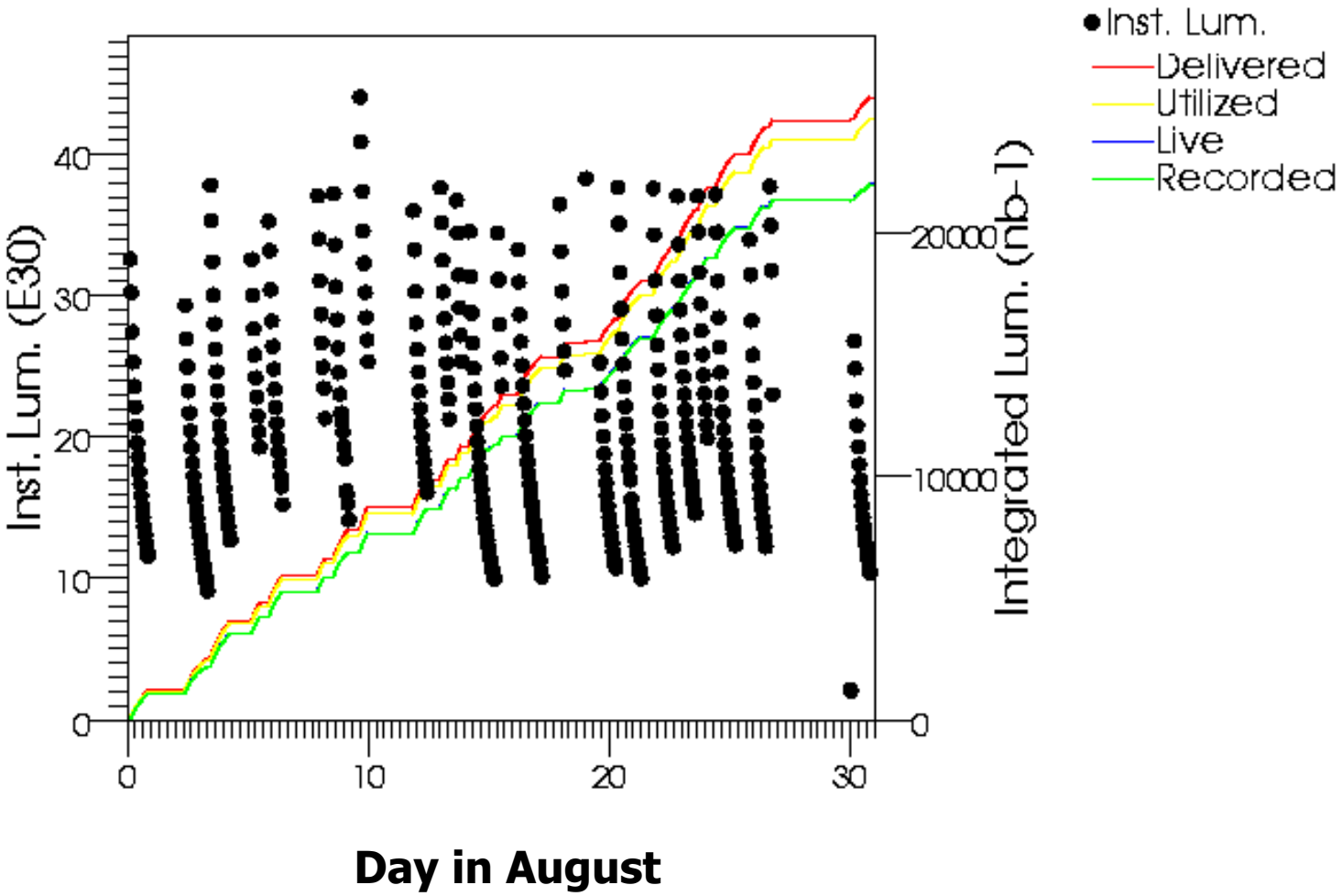
Trigger/ DAQ

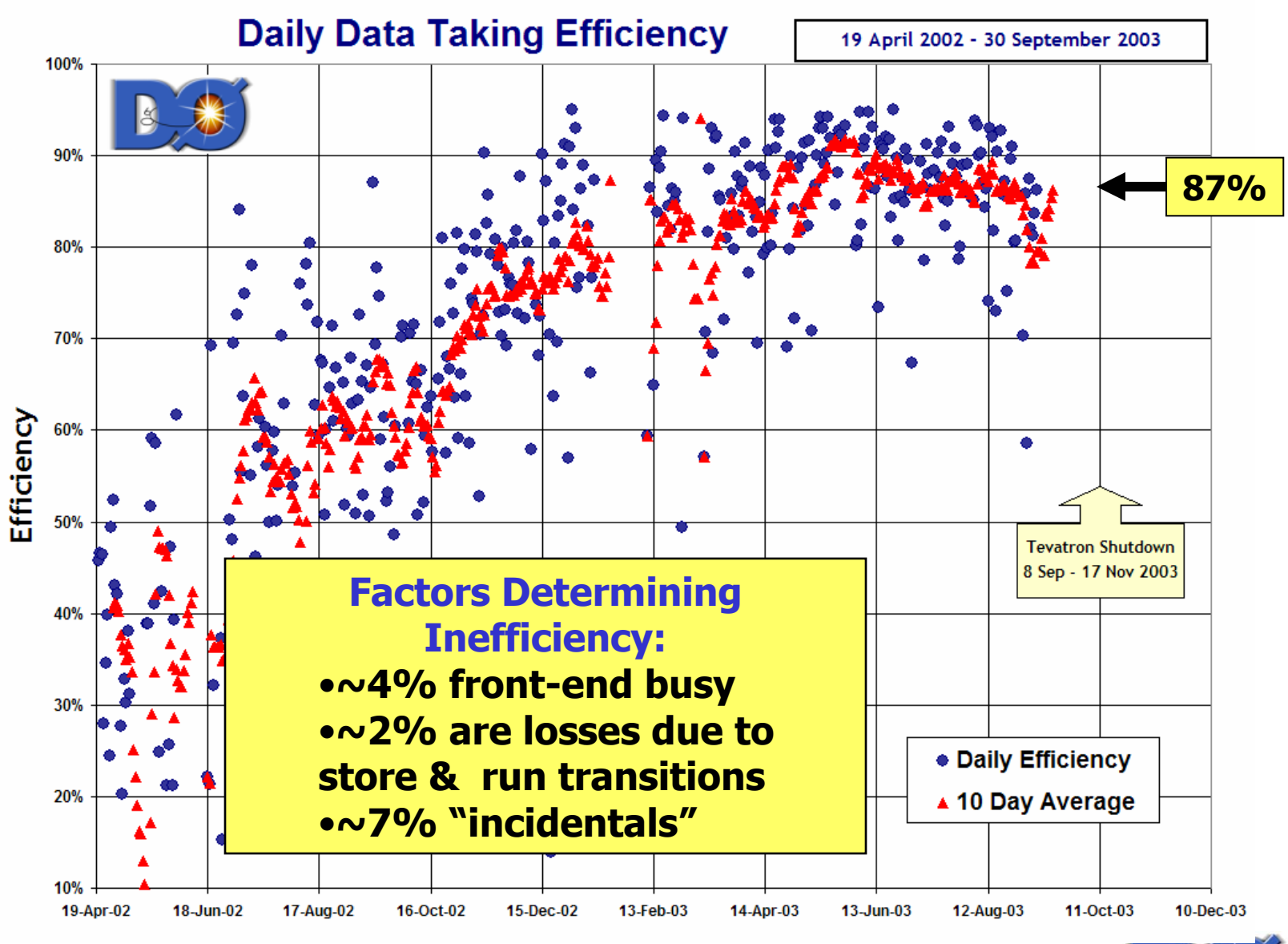


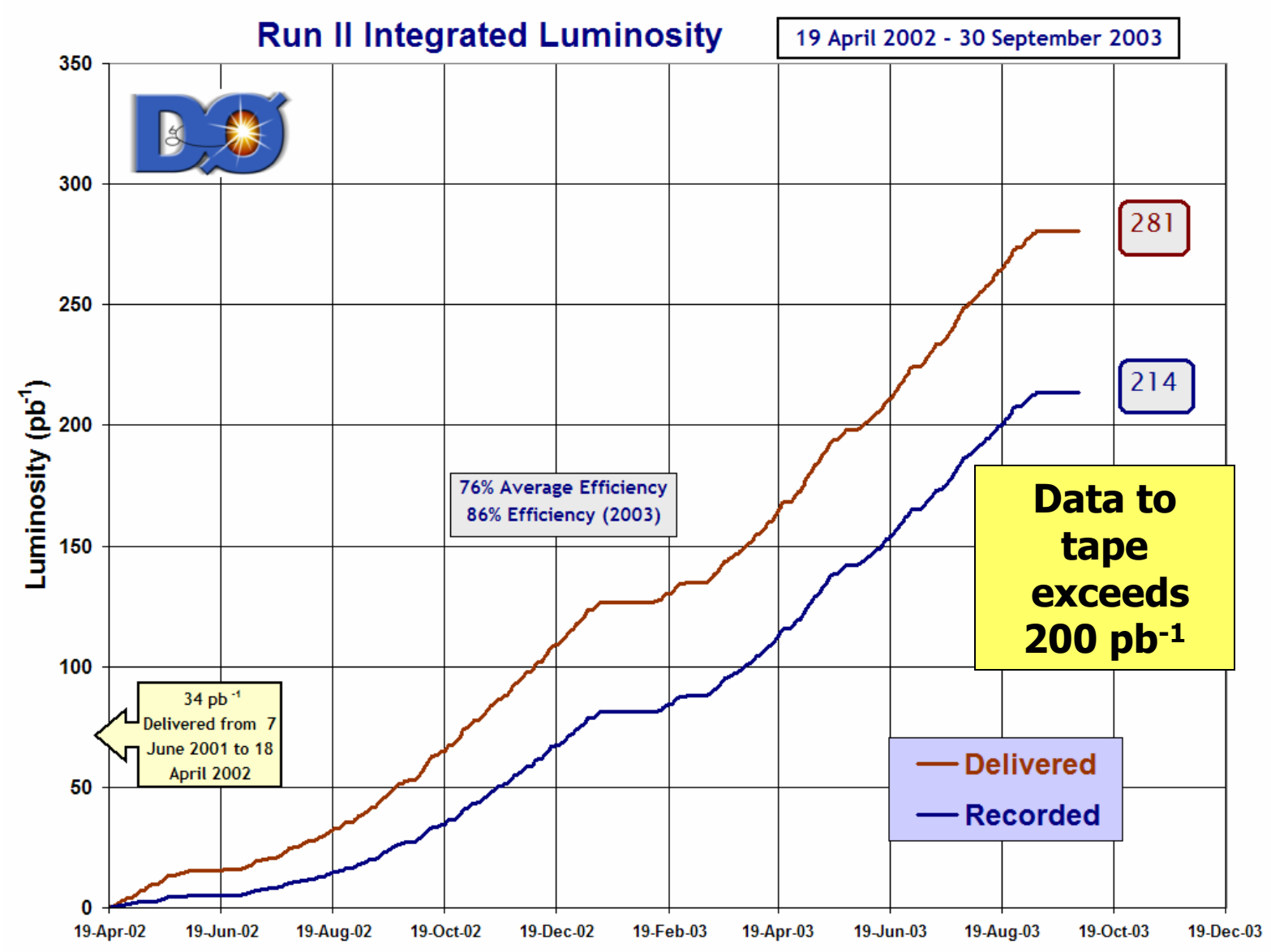
- Runs comfortably to 4E31 $cm^{-2}s^{-1}$ and will keep pace with luminosity growth as tracking triggers completed, CPUs added.
- L1
  - Operating with Cal, Muon, CTT/CPS
  - >100 independent trigger bits
- L2
  - Operating with CAL, Muon, CTT PS
  - Processor upgrade just completed
  - STT integration will be complete soon
  - >100 bits
- L3
  - Extensive suite of filters available
  - >250
- DAQ
  - Working to reduce Front End Busies.



Recent Tevatron/DZero Performance

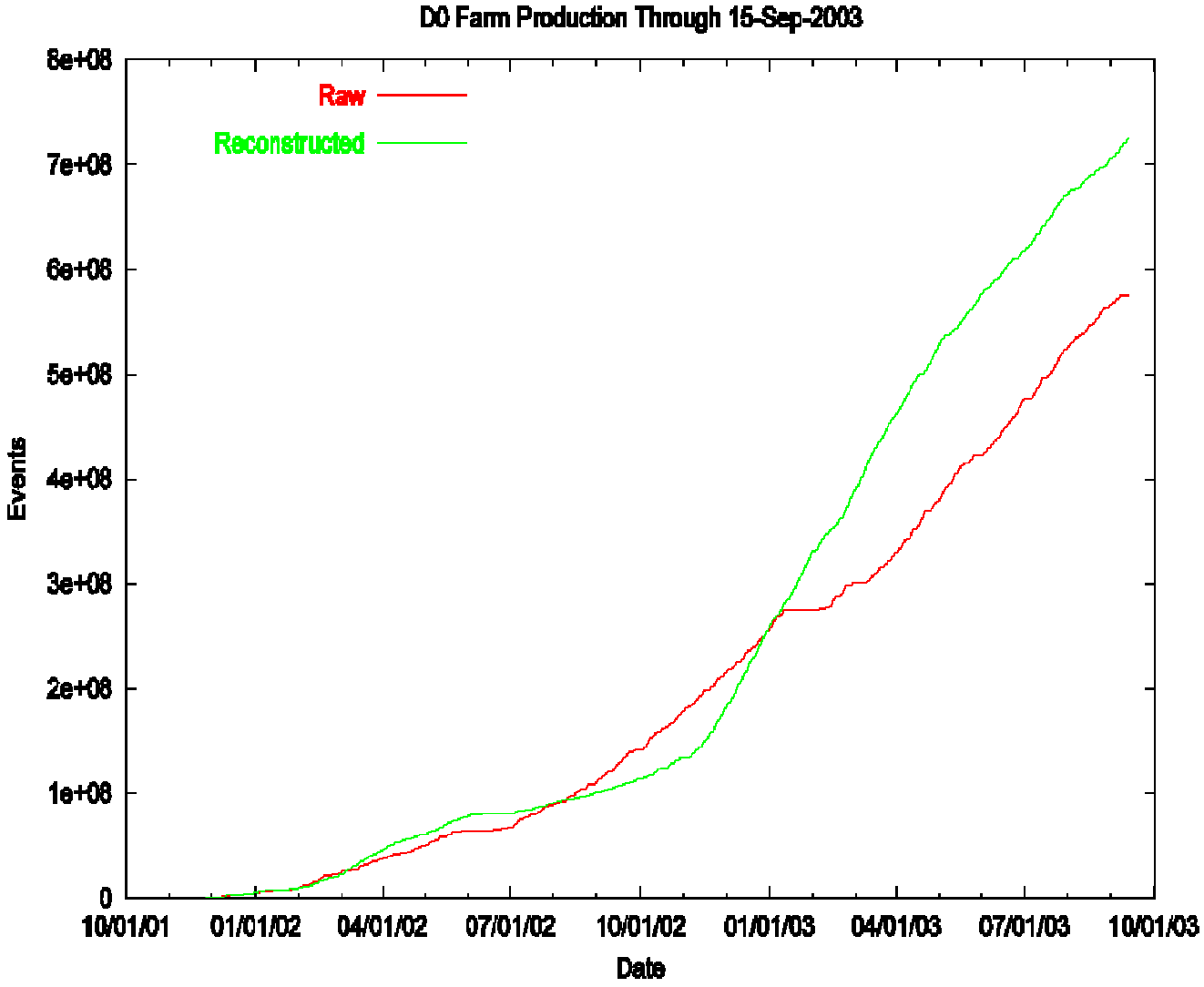



Daily Data Taking Efficiency
19 April 2002 - 30 September 2003
Efficiency
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
19-Apr-02
18-Jun-02
17-Aug-02
16-Oct-02
15-Dec-02
13-Feb-03
14-Apr-03
13-Jun-03
12-Aug-03
11-Oct-03
10-Dec-03
87%
Tevatron Shutdown
8 Sep - 17 Nov 2003
Factors Determining Inefficiency:
•~4% front-end busy
•~2% are losses due to store & run transitions
•~7% "incidentals"
Daily Efficiency
10 Day Average


Run II Integrated Luminosity
19 April 2002 - 30 September 2003
Luminosity (pb-1)
350
300
250
200
150
100
50
0
281
214
76% Average Efficiency
86% Efficiency (2003)
Data to tape exceeds 200 pb-1
34 pb-1 Delivered from 7 June 2001 to 18 April 2002
Delivered
Recorded
19-Apr-02
19-Jun-02
19-Aug-02
19-Oct-02
19-Dec-02
19-Feb-03
19-Apr-03
19-Jun-03
19-Aug-03
19-Oct-03
19-Dec-03

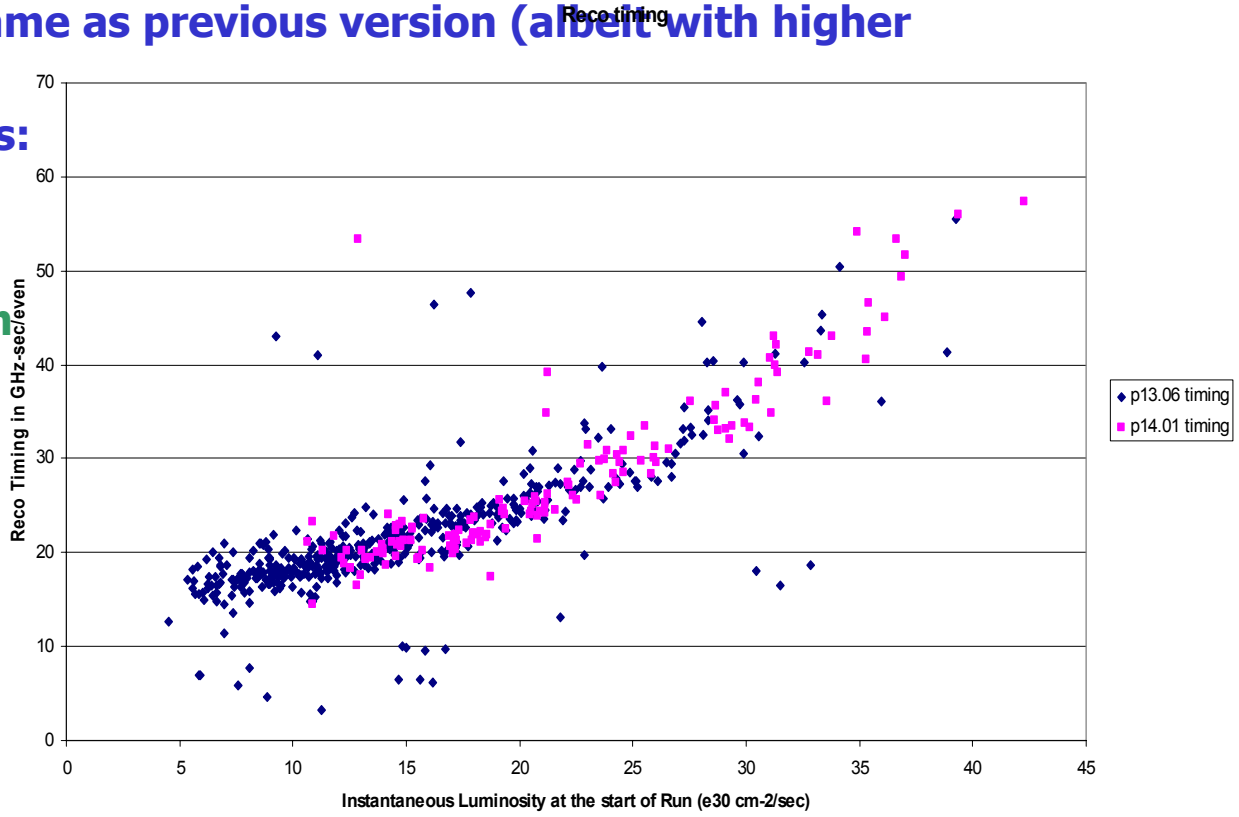
Reconstruction Strategy

- Primary processing done on Fermilab Farms.
  - Sufficient capacity to keep up with data stream
    - About 10M events/wk
  - All pre-shutdown data completed this week
- Reconstruction performed with two versions
  - P13 prior to June 24th, 2003
  - P14 thereafter – has superior tracking
- Will cycle through all data prior to June 24th with P13
  - Using onsite farms
  - Balance with offsite farms (Michigan, Lyon, Karlsruhe…)


D0 Farm Production Through 15-Sep-2003
Raw
Reconstructed
Events
8e+08
7e+08
6e+08
5e+08
4e+08
3e+08
2e+08
1e+08
0
10/01/01
01/01/02
04/01/02
07/01/02
10/01/02
01/01/03
04/01/03
07/01/03
10/01/03
Date

Reconstruction Time

- CPU time is measured in 10's GHz sec / event → importance for offsite processing
- Grows with instantaneous luminosity
- Current version ~ same as previous version (albeit with higher tracking efficiency)
- Speed improvements:
  - ~30% C++ improvements
  - ~20% Algorithm optimization



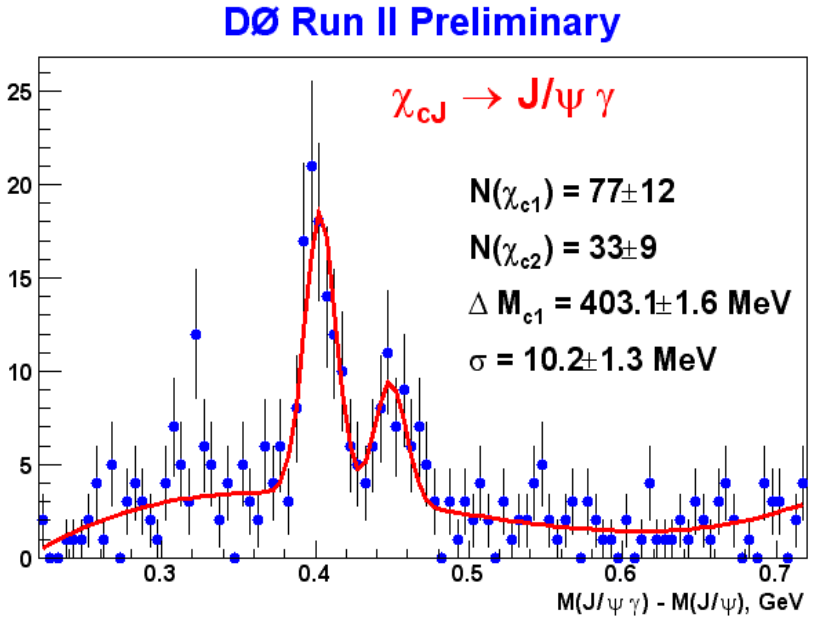
Physics Presented @ LP2003

- **masses, or scale limits**
  - $M(B^{**}_d) = 5.71 \pm 0.016$ GeV
  - $m(\chi_0^1) > 80$ GeV
  - $m_{1/2} > 150$ GeV
  - $M_S(GRW) > 1.28$ TeV ($ee/\gamma\gamma$)
  - $M_S(GRW) > 0.88$ TeV ($\mu\mu$)
  - $M_{LQ}(\mu\mu) > 184$ GeV
  - $M_{LQ}(e\nu) > 159$ GeV
  - $M_{LQ}(ee) > 231$ GeV
  - $M_{Z'}(ee) > 719$ GeV
  - $M_{Z'}(\mu\mu) > 620$ GeV
  - $M(H^{\pm\pm}) > 115$ GeV
- **BR and R**
  - $BR(B_s \to \mu\mu) < 1.6 \times 10^{-6}$
  - $R_{W/Z} = 10.34 \pm 0.35 \pm 0.48$
- **lifetimes**
  - $\tau(\text{incl. B}) = 1.562 \pm 0.013 \pm 0.045$ ps
  - $\tau(B^+) = 1.65 \pm 0.083\ ^{+0.096}_{-0.1233}$ ps
  - $\tau(B_d) = 1.52\ ^{+0.19}_{-0.17}$ ps
  - $\tau(B_s) = 1.19\ ^{+0.19}_{-0.14}$ ps
  - $\tau_{\Lambda b} = 1.05\ ^{+0.21}_{-0.18} \pm 0.12$ ps
  - $\tau(B \to D\ell\nu) = 1.46 \pm 0.08$ ps
- **cross sections, or limits**
  - $\sigma(tt) = 8.1^{+2.2}_{-2.0}\ ^{+1.6}_{-1.4} \pm 0.8$ pb
  - $\sigma(Z\mu\mu) = 261.8 \pm 5.0 \pm 8.9 \pm 26.2$ pb
  - $\sigma(Z\tau\tau, \pi\text{–type}) = 235 \pm 137$ pb
  - $\sigma(Z\tau\tau, \rho\text{-type}) = 222 \pm 71$ pb
  - $\sigma(W+bb) < 33.4$ pb
  - $\sigma * BR(H \to WW \to ee/e\mu) < 0.45$ to 2.8 pb
  - $\sigma * BR(H \to WW \to \mu\mu) < 0.2$ to 0.7pb

b-Physics: Resonances

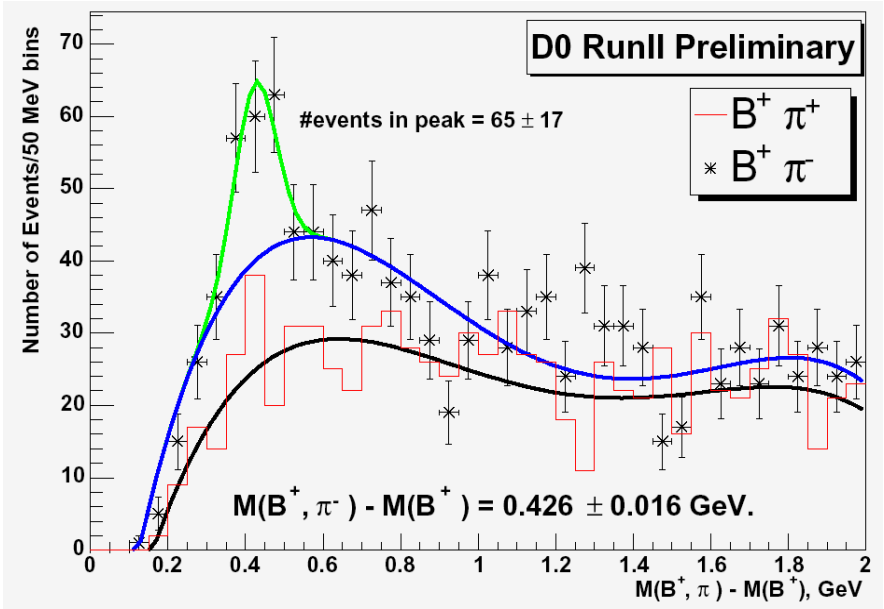
$$\chi_c \rightarrow J/\psi\,\gamma$$

- Theoretical production not understood
- can resolve two mass peaks
  - χ_{c1} and χ_{c2}
  - given spins, don't expect equal production
- $N\chi_{c1}$ = 77 ± 12 evts; $N\chi_{c2}$ = 33 ± 9 evts



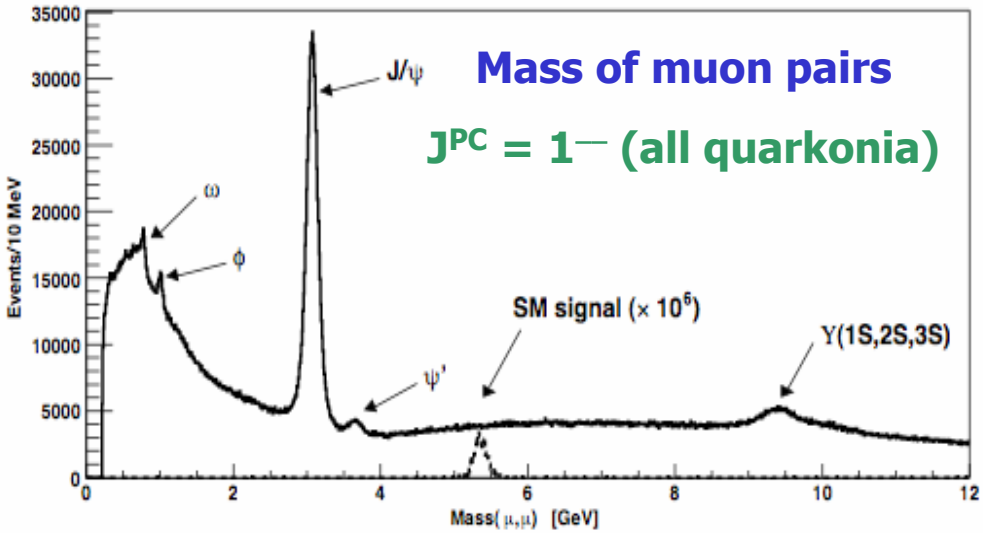
$$B_d^{**} \rightarrow B^+\pi$$

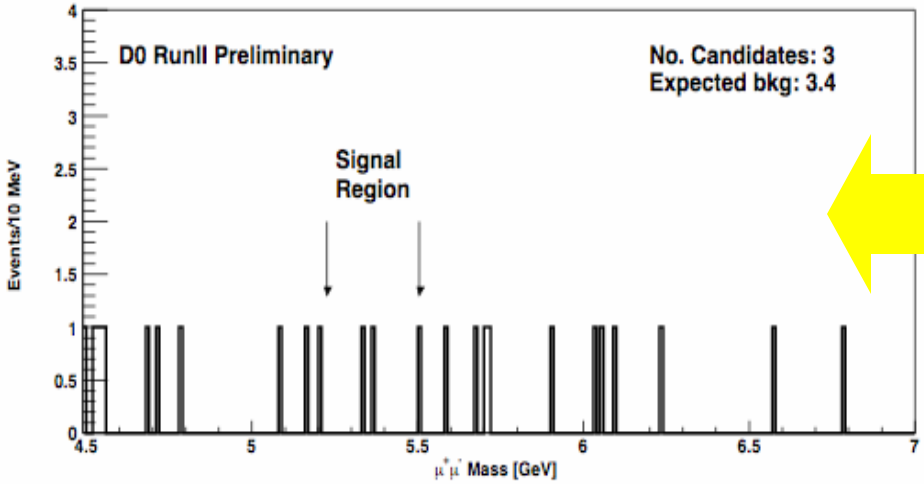
- Fully reconstructed decays with 114 pb-1
- First Observation at the Tevatron
  - 5.71 +/- 0.016 GeV
  - 5.698 +/0 .008 GeV (PDG)



b-Physics: Indirect searches for new particles

- Measure the rate of the rare decay $B_s \rightarrow \mu^+\mu^-$
- In the Standard Model, cancellations lead to a very small branching ratio
  - SM BR= 3.7×10^{-9}
- New particles (e.g. SUSY) contribute additional Feynman diagrams, increase BR
  - up to 10^{-6}



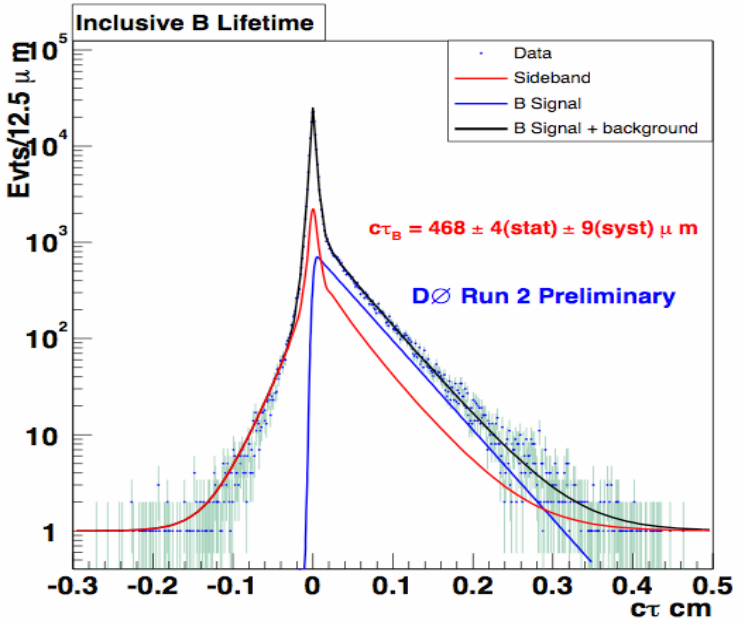


- In $100pb^{-1}$ of data, after all cuts, in B_s mass region
  - Observe 3 events
  - Expect 3.4 ± 0.8 background
  - BR ($B_s \rightarrow \mu^+\mu^-$) < 1.6×10^{-6} (90% CL)
  - 2.0×10^{-6} (PDG)

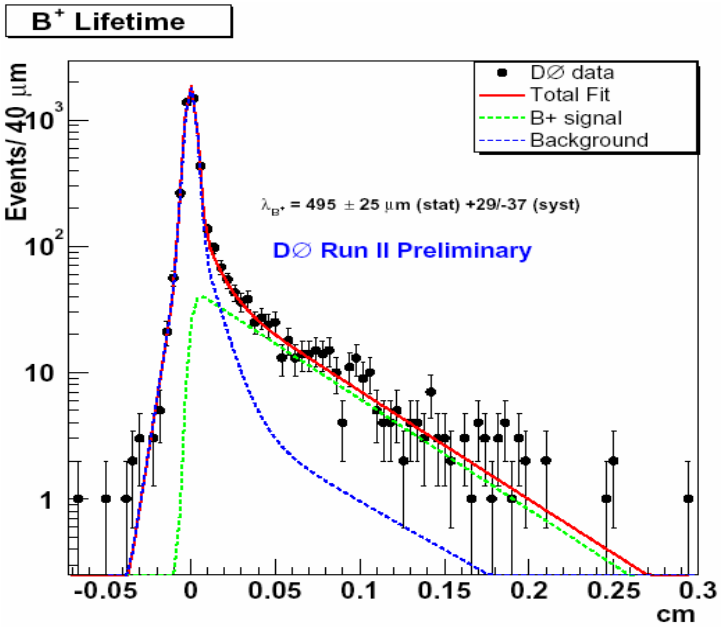
b-Physics: Lifetime Measurements

- **Inclusive lifetime**
  - 300k J/ψ's from 114 pb^{-1}
  - 1.562 ± 0.013 (stat.) ± 0.045 (sys.) ps
  - 1.564 ± 0.014 (PDG)

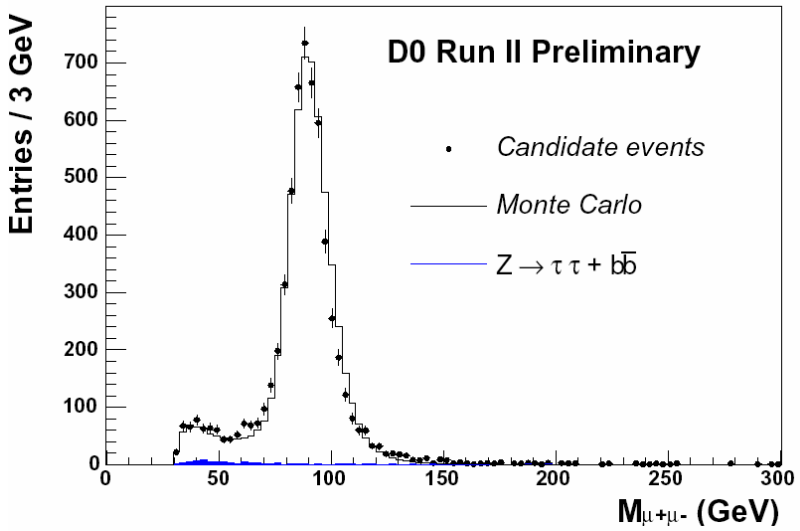
$$B \rightarrow J/\psi + X$$



- **Charged B lifetime**
  - mass: 5.272 ± 0.005 GeV
  - 1.65 ± 0.08 (stat.) ± 0.012 (sys.) ps
  - 1.671 ± 0.018 ps (PDG)

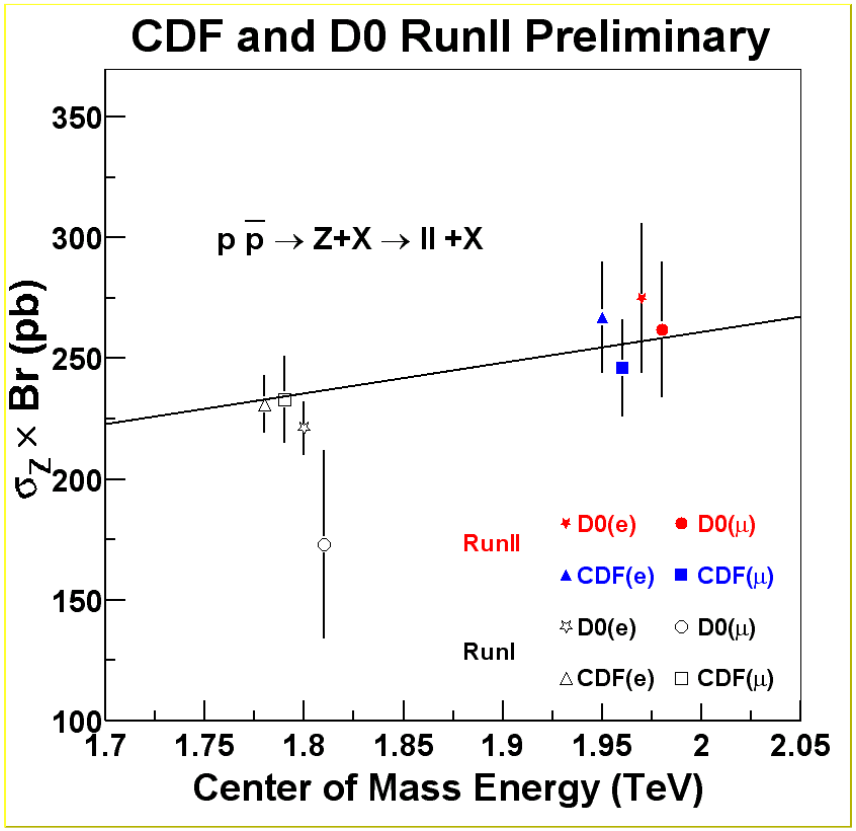


Electroweak: W and Z Cross Sections



- **Z->μμ cross section**
- **6126 events in 117 pb^{-1}**

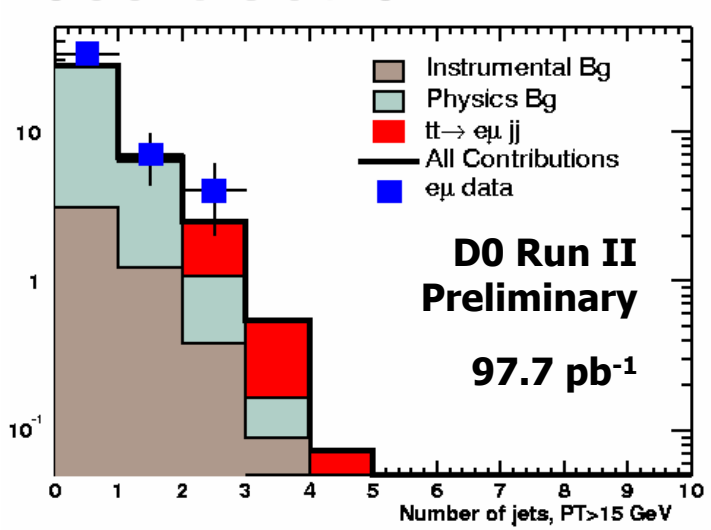
σ*Br = 261.8 ± 5.0 (stat) ± 8.9 (sys) ± 26.2 (lum) pb



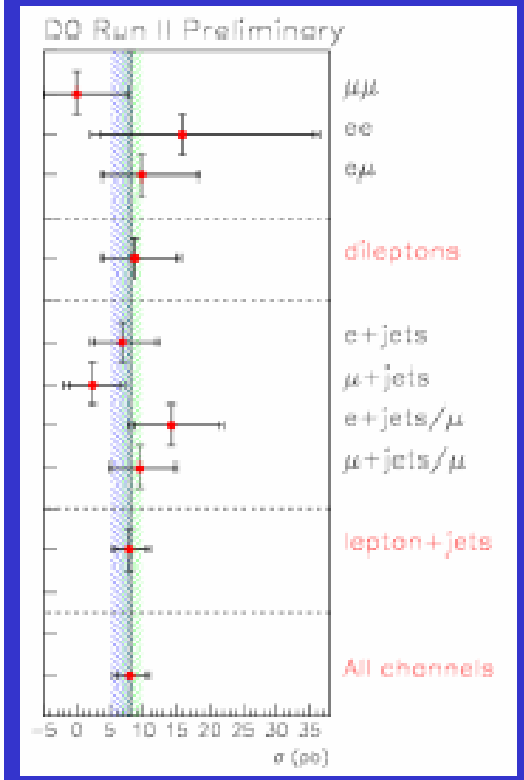
Top Physics: Production Cross Section

We measure

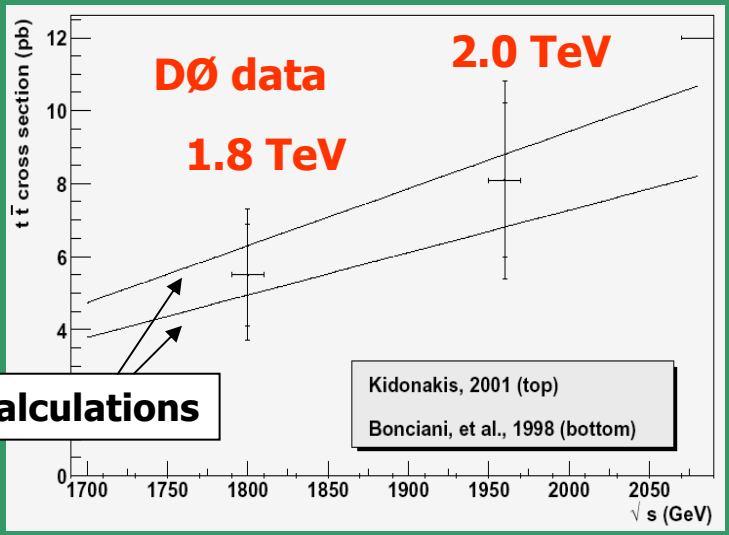
$$\sigma = 8.1\,^{+2.2}_{-2.0}\,(stat)\,^{+1.6}_{-1.4}\,(syst) \pm 0.8\,(lumi)\,pb$$



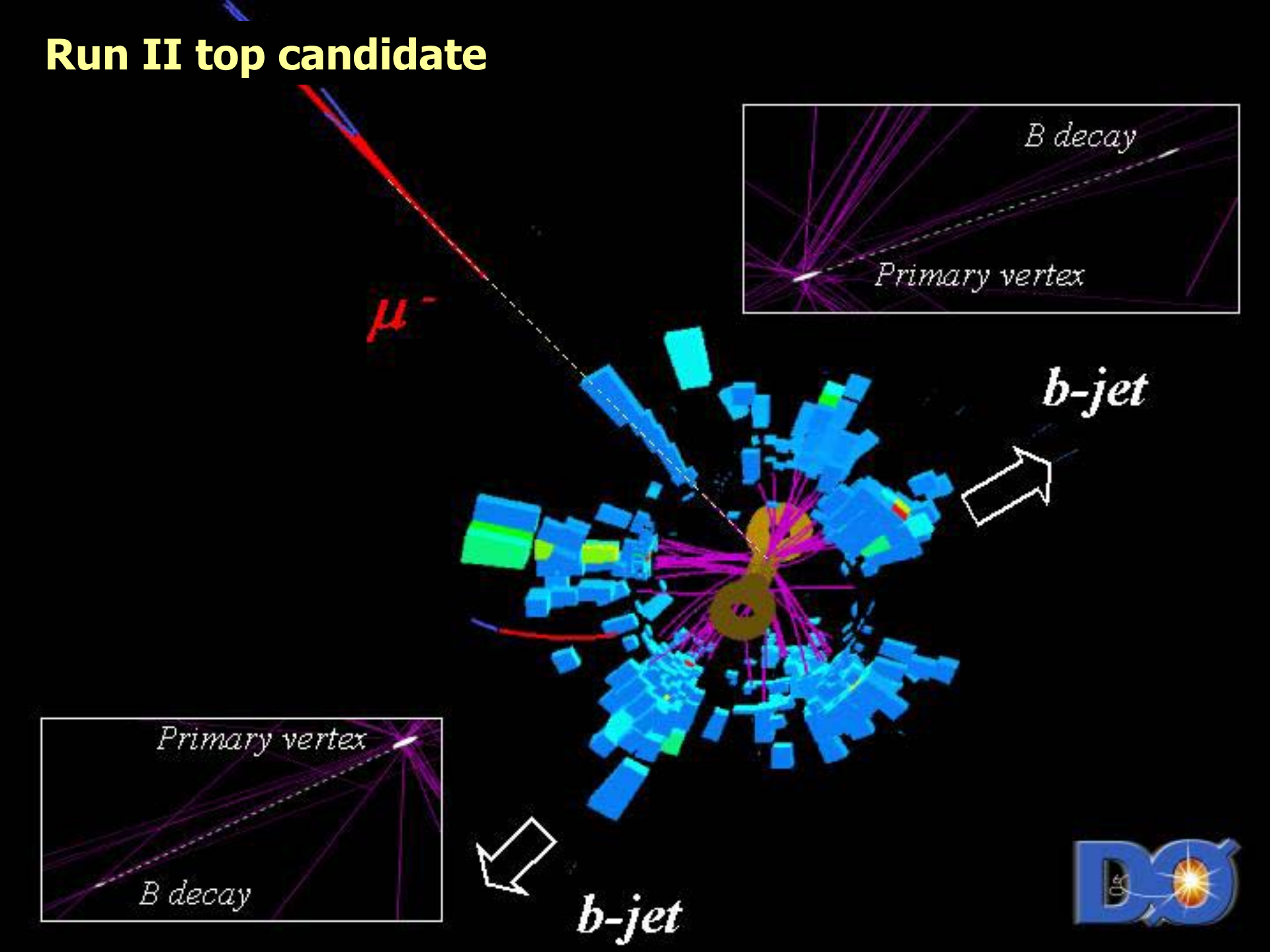
Is it consistent across all the various decay modes of the top quark?



Is it as expected from QCD?

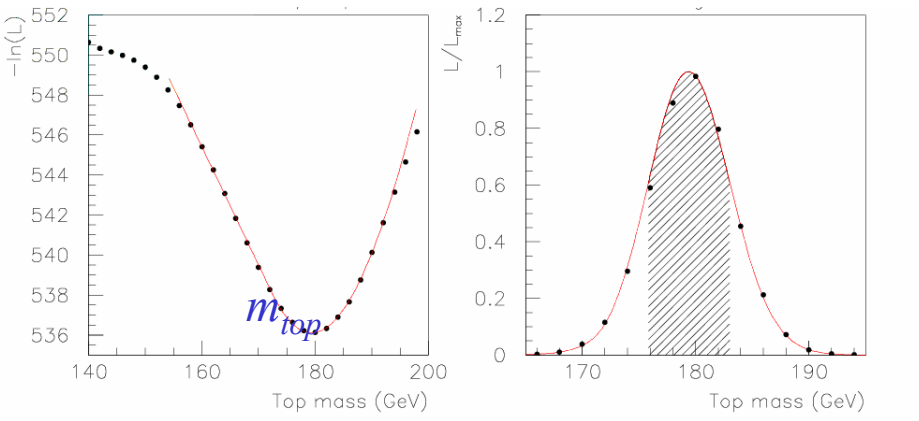


Run II top candidate



Top mass

- **Improved techniques**
  - **e.g. new DØ Run I mass measurement extracts a likelihood curve for each event**
  - **equivalent to a factor 2.4 increase in statistics:**
  - **m_{top} = 180.1 ± 5.4 GeV**



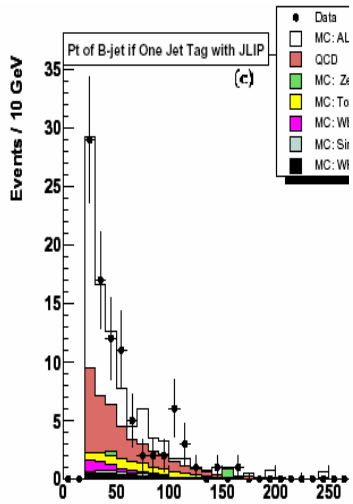
cf 174.3 ± 5.1 GeV (all previous measurements combined)

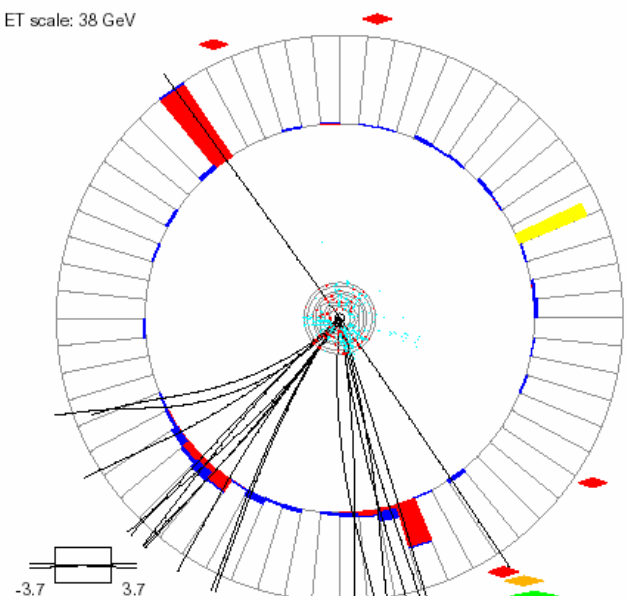
- **We can look forward to improved precision on m_t in the near future**
  - **Expect ~ 500 b-tagged lepton+jets events per experiment per fb^{-1}**
    - **cf. World total at end of Run I ~ 50**

Higgs Searches with 100-120 pb^{-1}

- **W(eν)+bb cross section**
  - Background for Higgs search
  - 92 evts w/ IP tag
  - 3 evts w/ double IP tag
  - 5.5 ± 1.6 evts background

  σ(W+bb) < 33.4 pb @ 95% c.l.



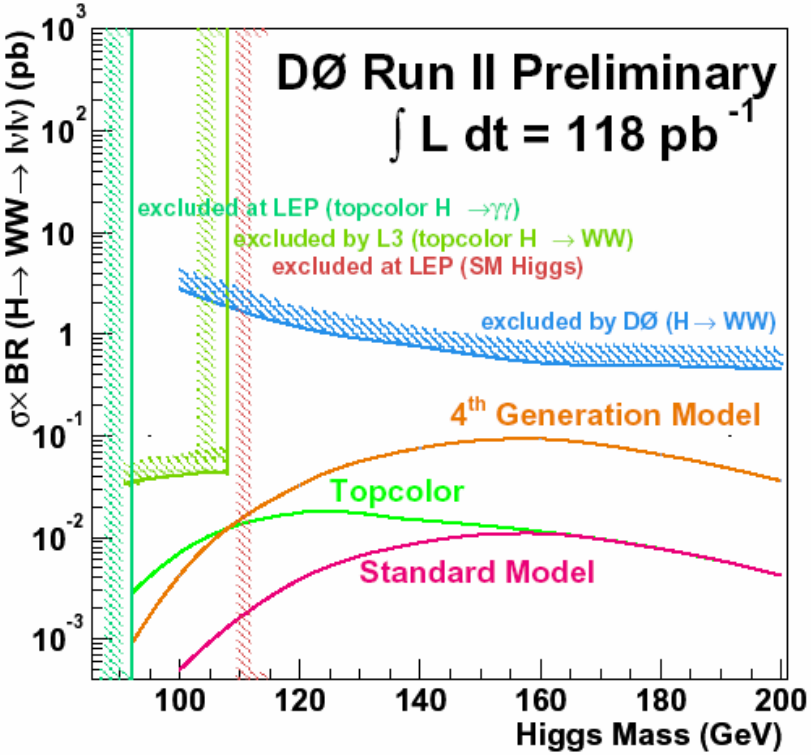


- **H → WW final state**
  - *ee*: 0 obs., 1.1 ± 0.8 background
  - *e*μ: 1 obs., 0.9 ± 0.5 background

  σ*BR < 0.45 pb to 2.8 pb

  $\mu\mu$: 1 obs., 0.9 ± 0.2 background

  σ*BR < 0.2 pb to 0.7 pb



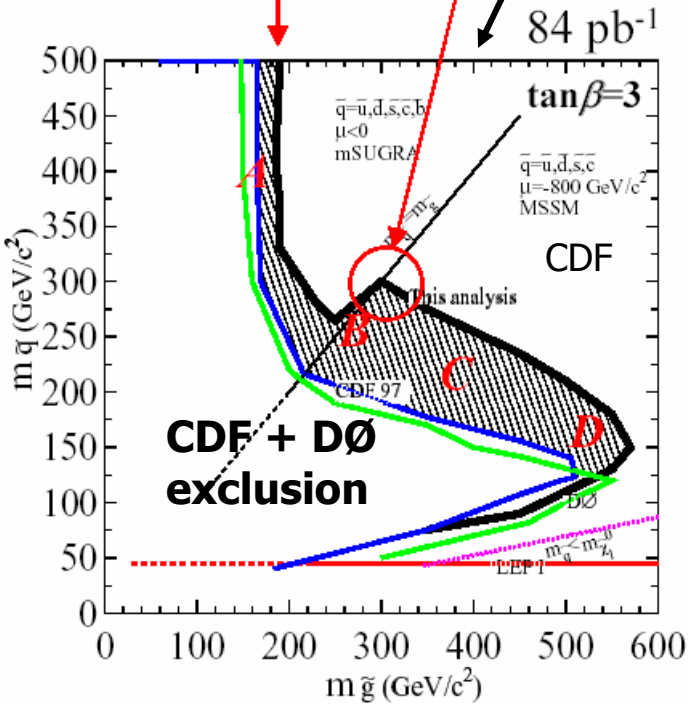
New Phenomena: Searching for squarks and gluinos

With 2 fb^{-1}: Reach in gluino mass ~ 400 GeV

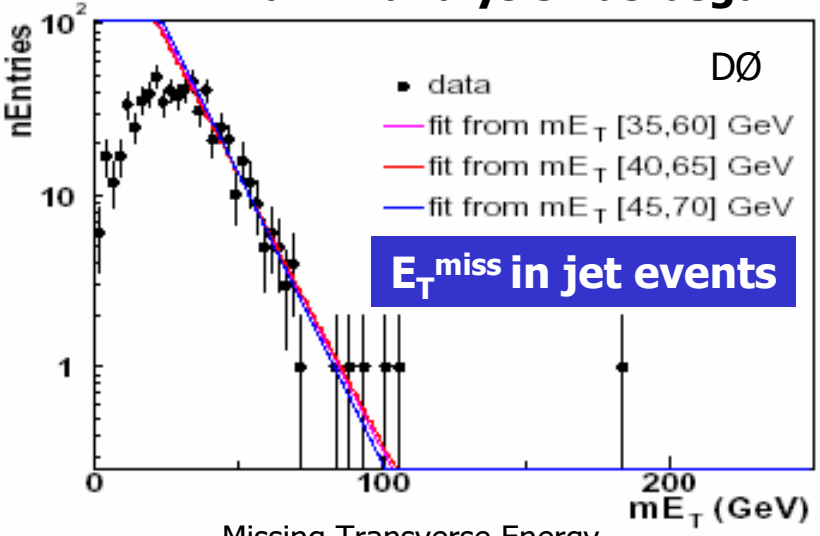
Run I

$M_{\tilde{g}} > 300\ \mathrm{GeV/c^2}$ $M_{\tilde{q}} \approx M_{\tilde{g}}$

$M_{\tilde{g}} > 195\ \mathrm{GeV/c^2}$



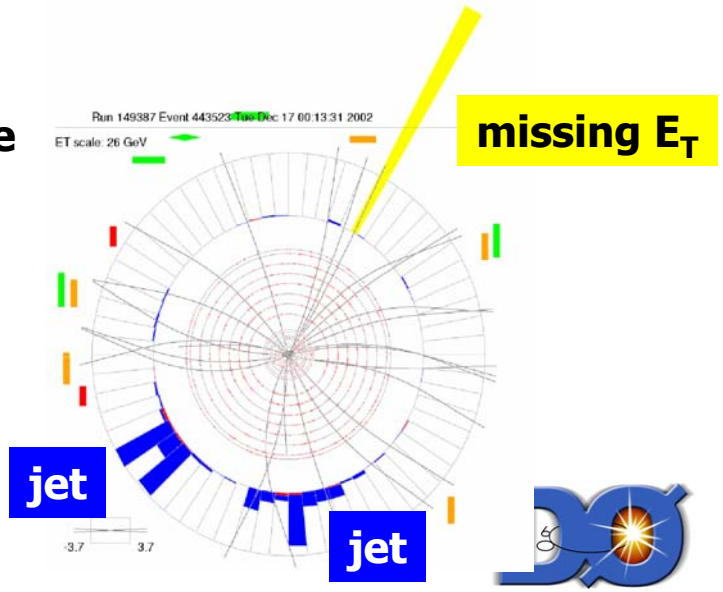
Run II analysis has begun:



Missing Transverse Energy

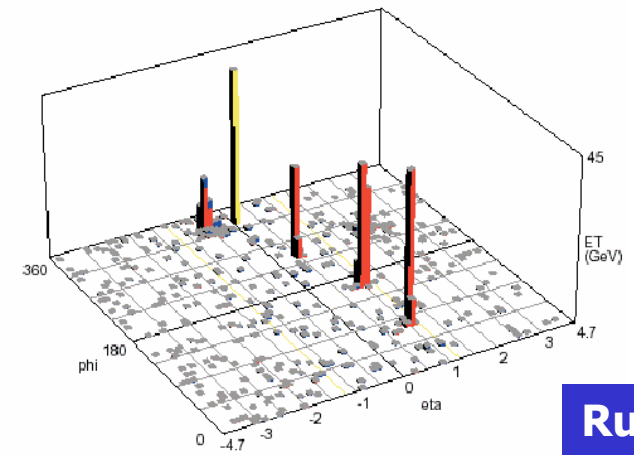
High ME$_T$ candidate event

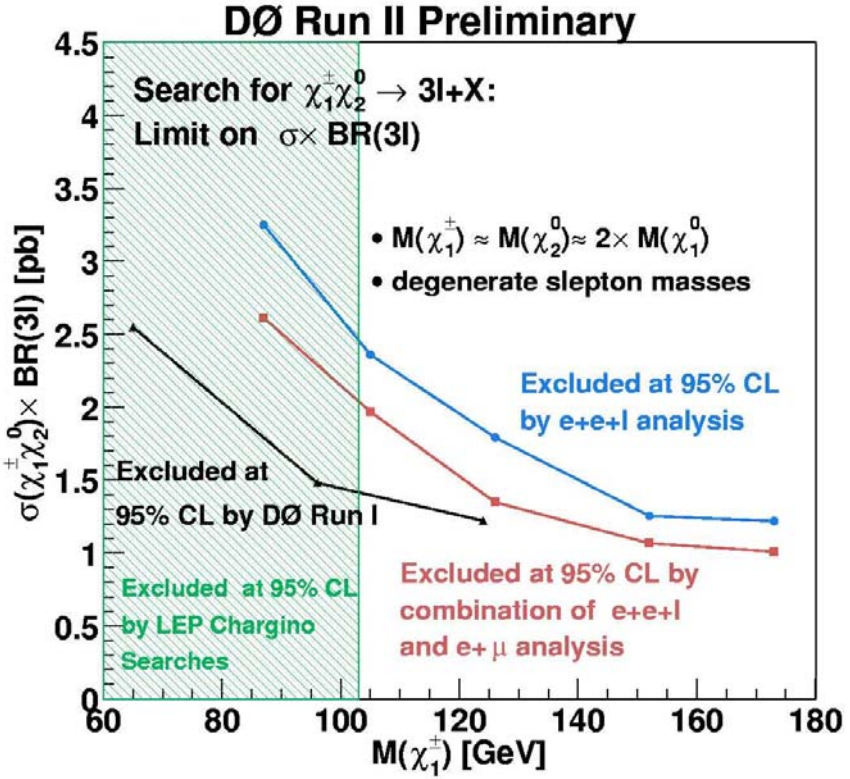
DØ



Chargino/neutralino production

- "Golden" signature
  - Three leptons
    - very low standard model backgrounds
- Increasingly important as squark/gluino production reaches its kinematic limits (masses ~ 400-500 GeV)
- Reach on $\chi^{\pm}$ mass
  ~ 180 GeV (tan β = 2, μ< 0)
  ~ 150 GeV (large tan β)



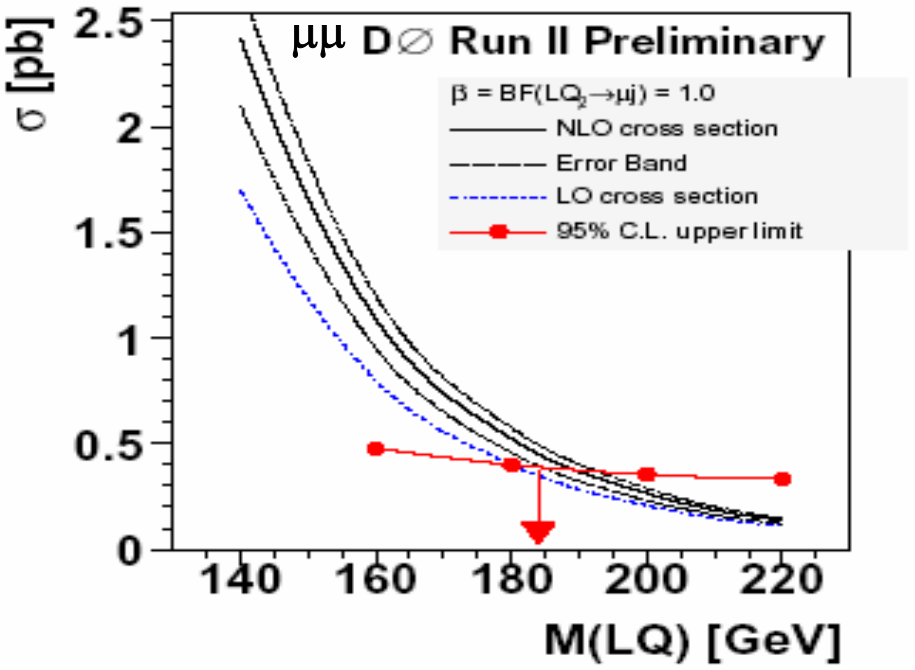


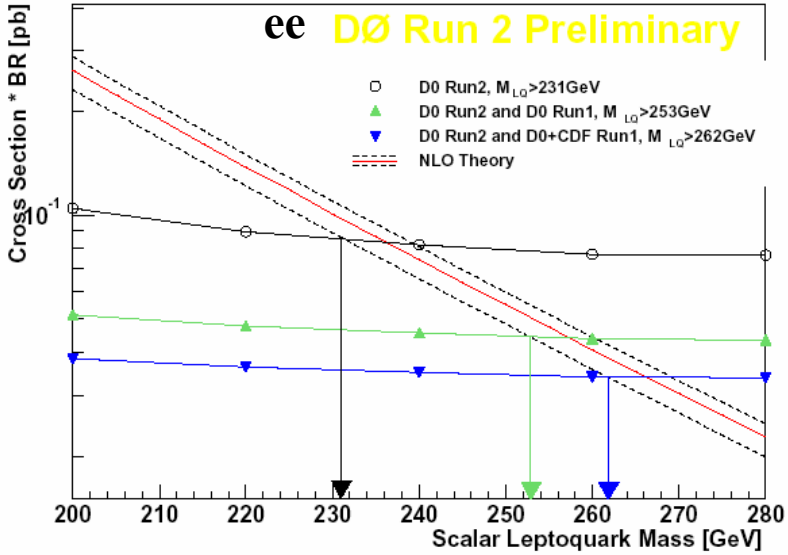
We have entered unexplored territory in terms of sensitivity to new physics

Run II Trilepton candidate event

Leptoquark Searches

- $\rightarrow \mu^+ q\ \mu^- q'$ **90 pb^{-1}**
  - backgrounds DY, ttbar, WW
  - $M_{LQ}(\beta=1) > 184$ GeV
- $\rightarrow e\ q\ \nu\ q'$ **121 pb^{-1}**
  - backgrounds: W+2j, γ+2j, top
  - 3 events obs, 4.24 ± 1.0 expected
  - assume BR 0.5, $M_{LQ} > 159$ GeV
- $\rightarrow e^+ q\ e^- q'$ **135 pb^{-1}**
  - backgrounds DY, ttbar, QCD multijet with elec. fakes
  - cross section < 0.086 pb
    - **$M_{LQ}(\beta=1) > 231$ GeV**
    - **Combined with Run1, get 253 GeV which is the most stringent limit to date**



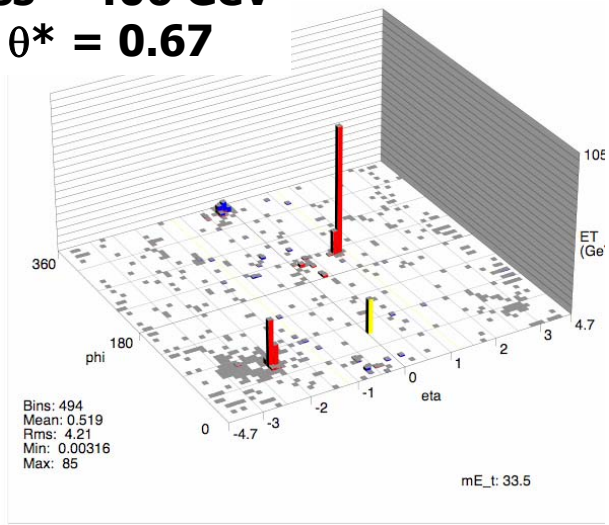


Searching for Extra Dimensions

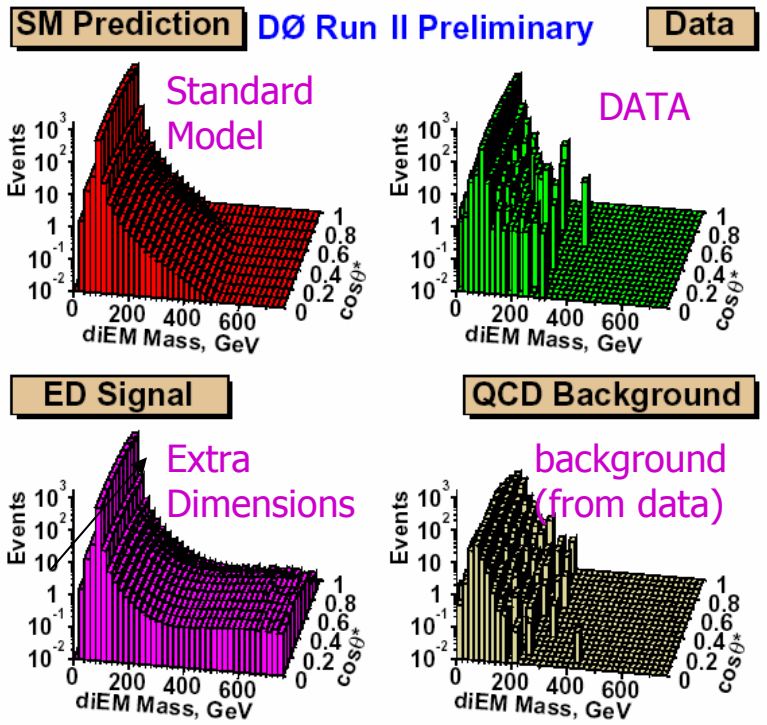
- **Signal would be an excess of ee, μμ, γγ events at large mass and large angle, due to virtual graviton exchange**

High-mass electron pair event

mass = 406 GeV
cos θ* = 0.67



$\bar{p}p \rightarrow ee$ and $\gamma\gamma$



DØ limits from $\bar{p}p \rightarrow ee, \mu\mu, \gamma\gamma$ (Summer 2003)

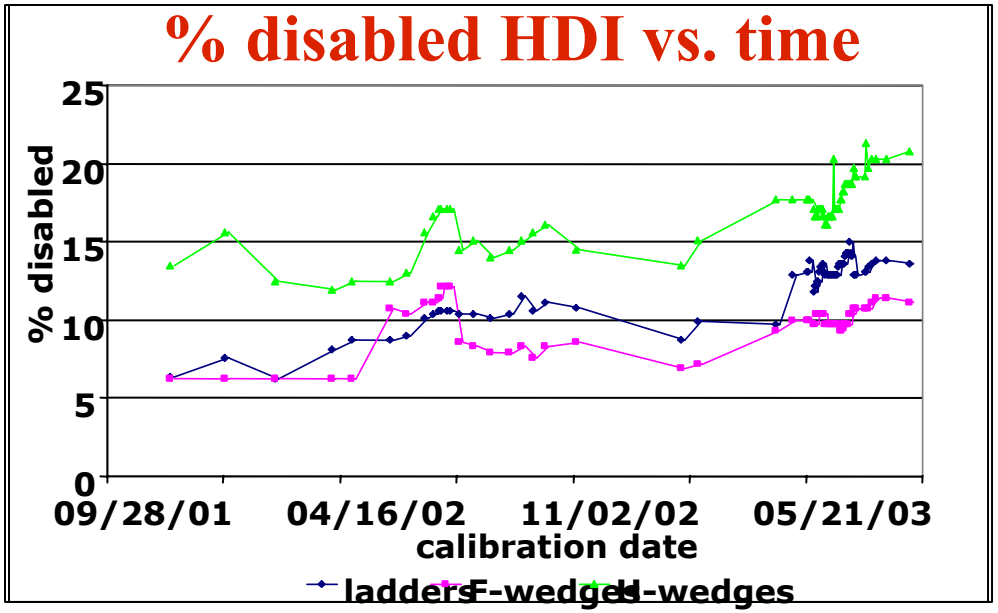
M_S(GRW) > 1.28 TeV (128 pb^{-1}, 95% CL)

> 1.37 TeV (Run I + Run II combined)

most stringent limit to date on large extra dimensions

Shutdown: Tracking

- Luminosity system
  - Spare cable installations
- Silicon
  - Repairs of failed electronics
  - Noise studies
  - Installation of coolant lines resistivity monitors
  - Replacement of TLDs
- Fiber tracker and preshowers
  - Maintenance/installation of upgraded LVPSs
  - Modifications of AFE boards to remove un-used SVX inputs from the readout to Reduce data size and front-end busy for the D0 detector
  - Maintenance of the VLPC He cooling system
- Forward proton detector
  - Maintenance and installation of electronics for full system operation



Shutdown: Calorimeter & Muon

- **Calorimeter**
  - Replacement of all large cooling fans for preamplifiers cooling
  - Modifications and tests of all Rack Monitor Interfaces
  - Study and hopefully fix noise (currently performing step by step power up of experiment)
- **Muon**
  - Access to A layer forward muon tracker: replacement of preamplifiers, gas leaks, gas monitors
  - Installation of extra trigger counters
  - Installation of ~200 remote power cycle relays for front-end electronics and all relevant cabling
- **General detector maintenance**
  - Air handlers, hydraulic systems, vacuum jackets, cooling water systems, ODH heads, etc.

Upgrade

- **In light of recent decision to cancel the SMT upgrade we are re-optimizing our efforts, a Layer-0 is under consideration**
- **Trigger upgrade remains largely intact, on budget and on time**
  - **Calorimeter clustering & digital filtering**
  - **Enhance track trigger to respond to increased occupancies**
  - **Calorimeter cluster match with track**
  - **Incremental Upgrades to Level 2, Level 3 Triggers and online system**

Trigger	Example Physics Channels	L1 Rate (kHz) (no upgrade)	L1 Rate (kHz) (with upgrade)
EM (1 EM TT > 10 GeV)	$W \to e\nu$ $WH \to e\nu jj$	1.3	0.7
Di-EM (1 EM TT > 7 GeV, 2 EM TT > 5 GeV)	$Z \to ee$ $ZH \to eejj$	0.5	0.1
Muon (muon p_T > 11 GeV + CFT Track)	$W \to \mu\nu$ $WH \to \mu\nu jj$	6	1.1
Di-Muons (2 muons p_T > 3 GeV + CFT Tracks)	$Z \to \mu\mu$, $J/\Psi \to \mu\mu$ $ZH \to \mu\mu jj$	0.4	< 0.1
Electron + Jets (1 EM TT > 7 GeV, 2 Had TT > 5 GeV)	$WH \to e\nu$+jets $tt \to e\nu$+jets	0.8	0.2
Muon + Jet (muon p_T > 3 GeV, 1 Had TT > 5 GeV)	$WH \to \mu\nu$+jets $tt \to \mu\nu$+jets	< 0.1	< 0.1
Jet+MET (2 TT > 5 GeV, Missing E_T> 10 GeV)	$ZH \to \nu\bar{\nu}b\bar{b}$	2.1	0.8
Muon + EM (muons p_T > 3 GeV+ CFT track + 1 EM TT > 5 GeV)	$H \to WW, ZZ$	< 0.1	< 0.1
Single Isolated Track (1 Isolated CFT track, p_T > 10 GeV)	$H \to \tau\tau$, $W \to \mu\nu$	17	1.0
Di-Track (1 isolated tracks p_T > 10 GeV, 2 tracks p_T > 5 GeV, 1 matched with EM energy)	$H \to \tau\tau$	0.6	<0.1
Total rate:		**~30 kHz**	**3.9 kHz**

Conclusions

- Detector operating well and efficiently
  - High Channel Count
  - Typically ~90% efficiency
  - Over 210pb^{-1} of data to tape
- Physics program in full swing
- Moving to maintain/upgrade

Good Return on Investment!